THE FRESHWATER GASTROPOD MOLLUSCS OF WESTERN ADEN PROTECTORATE

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THE FRESHWATER GASTROPOD MOLLUSCS OF WESTERN ADEN PROTECTORATE

C. A. WRIGHT

In the spring of 1962 a collection of freshwater gastropod molluscs was made during the course of an investigation into the transmission of human schistosomiasis in the Western Aden Protectorate. Material was collected in four areas, Abyan, an irrigated part of the coastal plain about 30 miles east of Aden, the Wadi Yeshbum in Upper Aulaqi near the border with the Eastern Protectorate, the Wadi Hatib south of Nisab, also in Upper Aulaqi and at Museimir in Haushabi, on the Wadi Tiban near to the Yemen border.

I am indebted to Dr. C. R. Jones, the Health Adviser, Aden Protectorate, and to Dr. J. Markham, Assistant Health Adviser, Western Aden Protectorate, for the facilities to carry out this work and for practical help in the field. I also wish to thank Mr. Andrew Fuller, Assistant Adviser, Upper Aulaqi, for his help and Mr. D. Claugher for his assistance both in the field and in the laboratory. The work was made possible by grant number E3650 from the U.S. Public Health Service.

HISTORICAL

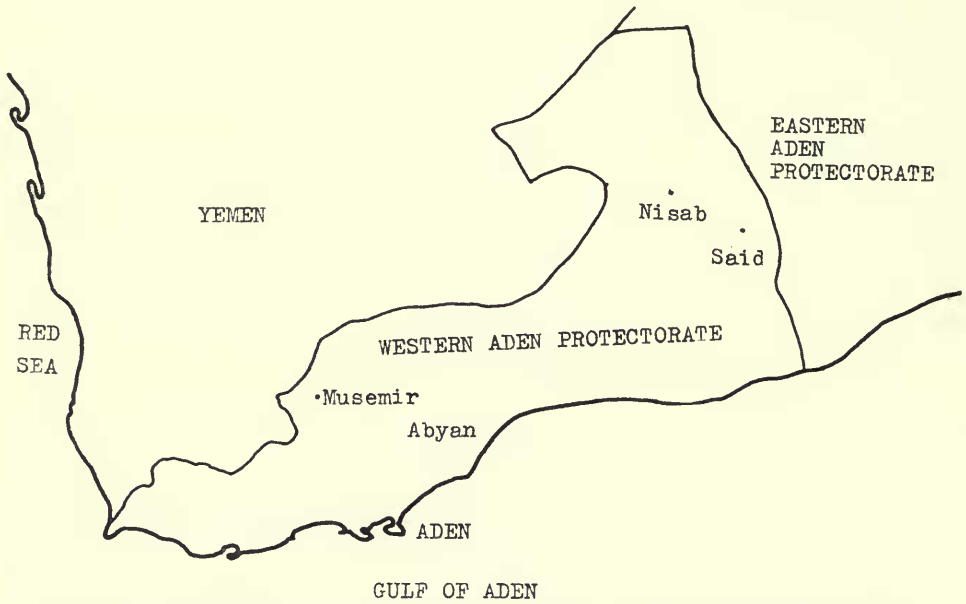
Paladilhe (1872) published descriptions of several land and freshwater molluscs from the area around Aden and his work provided the basis for subsequent reviews by Jousseaume (1889) and Ancey (1906), both of whom added further species to the known molluscan fauna of the area. Connolly (1941) reported on the non-marine mollusca collected by the British Museum (Natural History) expedition to Yemen and the Western Aden Protectorate and included an account of specimens collected by the Lord Wakefield expedition to the Hadhramaut. At the end of that paper Connolly gave a faunal list for Southern Arabia, based on Ancey's work but with additions. In recent years the only references to freshwater molluscs in South-west Arabia have been in reports of schistosomiasis surveys by Petrie & Seal (1943), Kuntz (1952), Ayad (1956), Azim & Gismann (1956) and Farooq (1961) but only the first of these was directly concerned with the Western Aden Protectorate.

Topography of the areas visited

The general topography of South-west Arabia was described by Scott (1939). The Western Aden Protectorate lies at the western end of the southern shore of the Arabian peninsula and extends inland for several hundred miles at its border with the Eastern Protectorate. There is a wide coastal plain of desert, broken in some places by barren outcrops of hills, and inland the folded ridges of mountains reach

heights of over 7,000 feet. To the north lie the mountainous areas of Yemen and to the north-east is the edge of the vast desert of Rub' al Khali.

Throughout most of the region bodies of permanent, fresh, surface water are rare. Rainfall is erratic in the lower hills, sometimes torrential, sometimes absent and much of the land surface is porous. In the highland areas there are more regular, heavy monsoon rains during which rivers flow through the inland valleys but few of them reach the sea except when occasional flash-floods descend, scouring the beds of the wadis which dissect the coastal plain. Cultivation in the uplands is mostly confined to valleys where the water table is high and wells provide a barely adequate water supply. In some of these areas springs occur, and short, permanent streams run above ground for distances varying from a few hundred yards to several miles



Map showing approximate positions of the areas in which collections were made.

before disappearing. This is the situation in the Wadi Hatib near Nisab in Upper Aulaqi State. Near the lower (north) end of the valley at Ma'rbah there are a number of small springs whose waters spread out to form a marshy area in which dense thickets of large reed-mace (*Typha*) thrive. In the rivulets and pools of this marsh there are many fish, frogs, aquatic insect larvae and snails. Further up the valley at Rassaiss there are one or two large springs which give rise to a clear gently flowing stream with deep, rocky pools in which fish are abundant and freshwater turtles also live. Snails are common in the shallow parts of the stream, also in a rock pool not connected with it in a cleft of the cliff above the main spring. Higher up the wadi at Tarbak a small river rising from a spring has cut a gorge in the otherwise barren floor of the valley. During its course of about a mile this stream passes through wide, almost still pools then runs over shallow, shingled beds before flowing

rapidly through a narrow, rocky channel and down a waterfall into a deep pool and on down the gorge. In this short but varied course there is a wide variety of habitats and this is reflected in the occurrence of a richer snail fauna than was found anywhere else in the Protectorate.

Further to the east in Upper Aulaqi State is Wadi Yeshbum, a relatively fertile valley with a high water table. A spring near As Sufal gives rise to a small, shallow stream which flows several miles toward the escarpment marking the boundary between the Eastern and Western Protectorates. Near Said and Yeshbum there are narrow gorges entering the main valley and in some of these there are deep rock pools which persist for long periods and may even be permanent.

In complete contrast to this terrain is Abyan, a low-lying irrigated district in the coastal plain about thirty miles east of Aden. This irrigation scheme owes its existence to the Wadi Bana, one of the few permanent rivers which reaches the coastal plain, and the Wadi Hasan which, although not wholly permanent has sections where springs give rise to small perennial streams in the river bed. Near the north end of the district the two wadis almost converge and the irrigation works have provided a link so that water from either source can be fed into the canal system. Near to this point is a permanent spring, independent of either wadi, whose water provides irrigation for vegetable gardens in the near-by village of Bateis. The general irrigation system is only in use seasonally and the principal snail habitats appear to be confined to a few parts of the permanent, natural waters in the wadis and the spring.

The Wadi Tiban at Museimir in Haushabi was the only other locality visited and it is in some respects intermediate in character between the habitats in Upper Aulaqi and those in Abyan. There is a permanent shallow stream flowing over the shingle bed of the wadi in a low-lying valley surrounded by hills. Despite its lower altitude (about 500 feet) the snail fauna at Museimir is the same as that at As Sufal in the Wadi Yeshbum (about 3,000 feet).

Family *PLANORBIDAE*

Biomphalaria rueppelli (Dunker)

(Pl. I, 1–8)

Planorbis rüppellii Dunker, 1848, p. 42.
Planorbis arabicus Melvill & Ponsonby, 1896, p. 3, Pl. I, figs. 15–17.
Biomphalaria arabica Connolly, 1941, p. 33.
Biomphalaria boissyi arabica Kuntz, 1952, p. 25.
Biomphalaria sp. (in part) Ayad, 1956, p. 90.

Upper Aulaqi: Wadi Yeshbum at Marbūm, As Sufal and Sumayfah, either in rock pools or gently flowing water, 3,000–3,200 ft.

Wadi Hatib, Ma'rbah and at Tarbak and Rassaiss, in streams, about 4,000–4,500 ft.

Haushabi: Museimir, in the Wadi Tiban in shallow, flowing water, about 500 ft.

The whorls of the shell are flattened above and bluntly angled beneath, the innermost are deeply sunk on the upper surface and the umbillicus is narrow. Apart from a well-marked spiral sculpture on most of the specimens this material does not differ

significantly in shell-form from material collected in the highlands of Ethiopia (Wright & Brown, 1962). The largest specimen found in Aden (at Sumayfah) measured 10·5 mm. in maximum diameter, 3·2 mm. umbilical diameter and 4·1 mm. in height. These dimensions are almost the same as those of the holotype of *B. arabica* (10.8, 3.65, 4.0).

The mantles of all the specimens dissected were uniformly darkly pigmented and without distinct markings. The penis sheath and preputium are approximately equal in length in most individuals but in a few the sheath is a little shorter than the preputium. The number of primary prostate diverticula is at least twelve in adult snails.

The mesocones of the lateral radula teeth are all triangular ; none of the arrow-head type were seen. Subdivision of the marginal ectocones is general but in some radulae the marginal ectocones may be undivided in one or two longitudinal rows (Fig. 5).

This species is widely distributed in South-west Arabia and is the dominant basommatophoran in areas away from the coast. The type locality for *B. arabica* is Dhofar in the Hadhramaut and Connolly (1941) records the species from several localities in the Western Aden Protectorate and Yemen. Through the kindness of Dr. Naguib Ayad of the Ministry of Public Health, Cairo, I have been able to examine shells of the specimens which he collected in Yemen and there is no doubt that his material also belongs to this species. Kuntz (1952) treated *arabica* as a sub-species of *B. alexandrina* (= *boissyi*) but the present study shows that it is correctly placed in the *pfeifferi* group. Jousseaume (1889) referred to the young planorbid recorded by Paladilhe (1872) from alluvial débris at Kursi, near Aden, as belonging to the *adowensis* group and it has recently been shown that *B. adowensis* is almost certainly not distinct from *B. rueppelli* (Wright & Brown, 1962).

B. ruepelli is found in practically every body of permanent fresh water in the part of Upper Aulaqi which was visited. The snails reach maturity at a relatively small size and lay large numbers of eggs. The population density in some rock pool habitats is very great and, with the large numbers present and their wide distribution, it is surprising that infection with *Schistosoma mansoni* is not a more serious public health problem than it appears to be.

Gyraulus convexiusculus (Hutton)

(Pl. I, 9–17)

Planorbis convexiusculus Hutton, 1849, p. 657 ; Connolly, 1941, p. 36.

Upper Aulaqi : Sumayfah, Wadi Yeshbum, from deep rock pools and shallow, flowing water, about 3,200 ft.

Tarbak, Wadi Amhadu (part of Wadi Hatib), from a slow-moving part of the stream, abundant on aquatic vegetation.

Lower Yafai : Nabwa spring, Bateis, Abyan, three very young specimens, probably belonging to this species.

The shells are small, flattened and the whorls do not increase in diameter so rapidly as they do in the common African species, *G. costulatus*. The mean dimensions of a

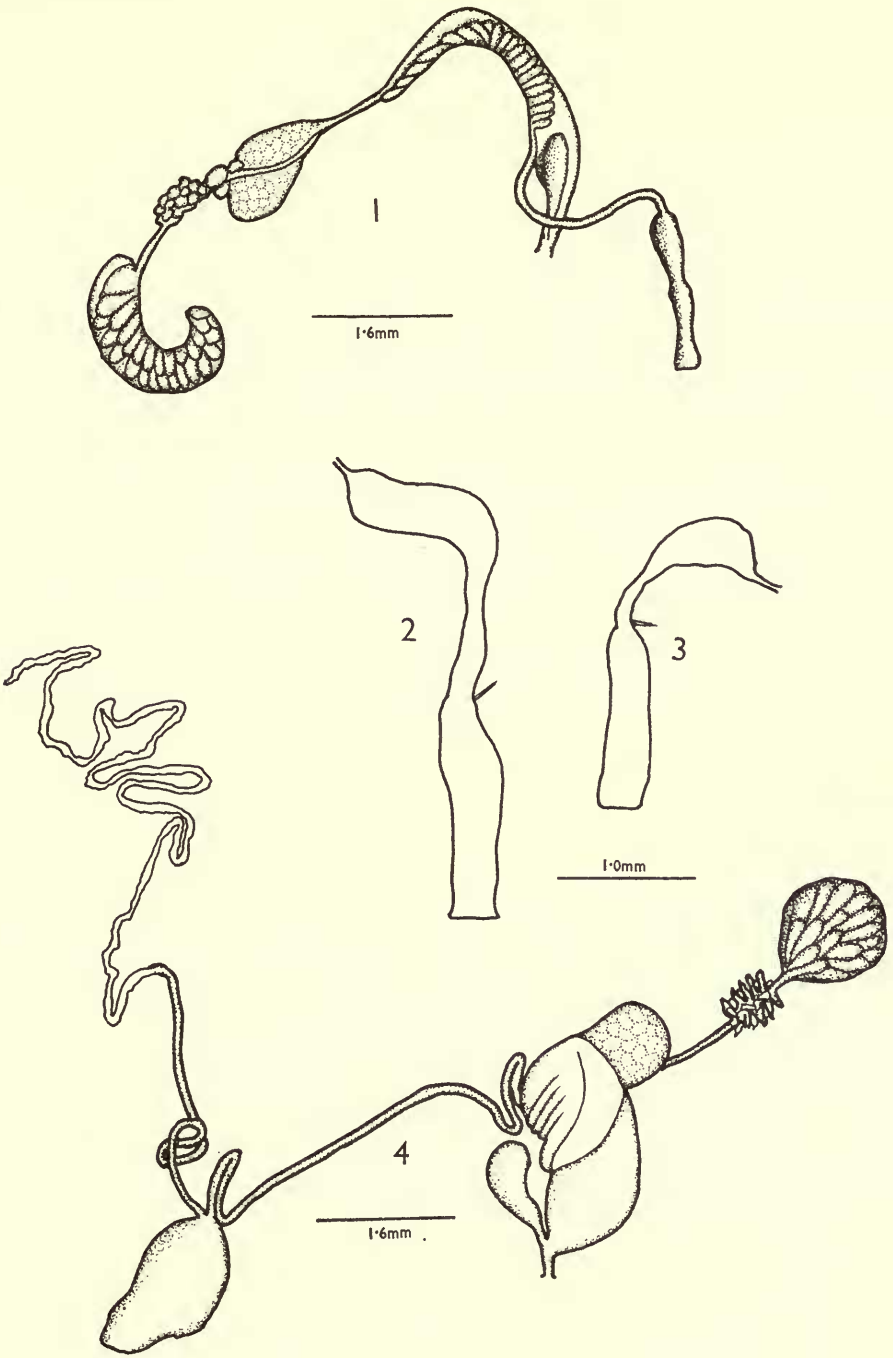


FIG. 1. *Gyraulus convexiusculus*. Complete reproductive system.
FIGS. 2 & 3. *Bulinus reticulatus*. Male copulatory organs of two individuals from Rassaiss.
FIG. 4. *Ancylus fluviatilis*. Complete reproductive system of specimen from Tarbak.

small sample of adult specimens from Tarbak are, diameter 4·3 mm., umbilicus 1·6 mm. and height 1·1 mm. There is no obvious angulation of the whorls and the aperture is roughly oval. There is a superficial, somewhat coarse spiral sculpture on most of the specimens, recalling the appearance of *G. kigeziensis nyanzae* Mandahl-Barth 1954.

Anatomically *G. convexiusculus* differs from *G. costulatus* in the less compact arrangement of the accessory genital glands, a reflection of the differences in shell-form between the two species (Text-fig. 1). The penis sheath and preputium are roughly equal in length but the proximal dilatation of the penis sheath is wider than the maximum diameter of the preputium. The structure of the penial stylet is the same as that described for *G. costulatus* (Wright, in press). The prostate in *G. convexiusculus* is long and has as many as eighteen primary diverticula without marked secondary branching. The radula teeth are very small (Text-fig. 6) and the cusps of the laterals are longer and more lanceolate than those of *G. costulatus*. There are six tricuspid laterals in each half-row, about five transitional teeth which resemble the laterals except in the division of the ectocone and about six marginals. The marginals have the ecto- and endocones divided into two cusps each, resulting in five-cusped teeth instead of the seven-cusped marginals in Angolan *G. costulatus*.

Connolly (1941) recorded this species from the Hadhramaut at Hureidha, Wadi Jedd. The present material is so close to a series collected at Kandahar (Afghanistan) by Hutton (possibly the type material, B.M. (N.H.) collection number 56.9.15.79) that there is no reason to consider it to be a separate species unless subsequent anatomical studies of topotype material reveal any marked differences.

Bulinus sericinus (Jickeli)

(Pl. II, 1–4)

Isidora sericina Jickeli, 1874, p. 194, Pl. III, fig. 2.
Bulinus truncatus Connolly, 1941 (in part), p. 33.

Upper Aulaqi: Tarbak, Wadi Amhadu (part of Wadi Hatib), from rushes and emergent grasses in an almost still pool, also on stones and rocks in a narrower, more rapidly flowing part of the stream, about 4,500 feet.

A large sample was collected and it includes a wide range of shell forms. Wright & Brown (1962) have discussed variation in this polymorphic species from the Ethiopian highlands and this material from Aden includes most of the forms described. The majority of the smaller specimens, some smooth-shelled, with or without inflated whorls, some strongly ribbed (var. *harpula* Pollonera), were collected on vegetation in an almost still part of the stream while larger individuals, most of them with exserted spires (*shackoi* Jickelli) were more abundant on rocks in rapidly flowing water.

Anatomically the Aden material differs from the Ethiopian populations studied earlier in that the majority are aphallic. This condition was found in only one of a large number of Ethiopian specimens. Euphallic individuals in the Tarbak sample have a copulatory organ similar to that described by Mandahl-Barth (1960) for *B. mutandensis*. The penis sheath is longer than the preputium and, at its maximum

diameter, it is also a little wider. The sheath is regularly banded with dark rings, the epiphallus is short and, in one specimen a slight proximal dilatation of the epiphallus was seen. The radula teeth of *B. mutandensis* are described by Mandahl-Barth as about twice the size of those of *B. truncatus* but the teeth of the specimens from Tarbak (Fig. 7) do not differ significantly from those of Ethiopian *B. sericinus*.

Ayad (1956) mentioned that Mandahl-Barth identified all of his bulinids from the highlands of Yemen as *B. sericinus* (Jickeli) and, after examining the Yemeni specimens named as *B. truncatus* by Connolly (1941), I think that this is a valid action. Connolly's material was all found between altitudes of 7,900 and 9,300 ft. A sample of six specimens in the collection of the British Museum (Natural History) collected by Dr. Haythornthwaite from Lower Yafai do not have an exact locality and the altitude at which they were found is not known. At the present time it seems that my sample from Tarbak is from the lowest altitude yet recorded (about 4,500 ft.) for this highland species.

The role of *B. sericinus* as an intermediate host for schistosomes is not yet certain. One of the specimens from Tarbak shed schistosome cercariae about two weeks after it was collected but the species of parasite has not been identified. A few snails from this sample were exposed to miracidia of *Schistosoma haematobium* hatched from a urine sample collected at Said but no cercariae were produced.

Bulinus reticulatus Mandahl-Barth 1954

(Pl. II, 5–8)

Bulinus truncatus (var.) Connolly, 1941, p. 37.

Upper Aulaqi : Wadi Yeshbum at Marbum, near Said, in rock pools in a narrow gorge, about 3,200 ft.

Rassaiss, Wadi Hatib, south-east of Nisab, in a moderate-sized pool in a cleft of a small cliff at the head of a gulley, about 4,000 ft.

The shells of these specimens compare well with those of a small sample from the type locality, Kisumu in Kenya. Those from Said tend to have the spire more exserted and those from Rassaiss are uniformly globular with a pronounced spire. The largest specimen collected (from Said) had a shell-length of 6·1 mm., aperture length of 3·7 mm. and maximum width of 4·0 mm. The mean length of twenty shells from Said was 4·9 mm. and from Rassaiss 5·1 mm. The mean ratio of shell-length to aperture length is 1·6 in both samples but the more globular specimens from Rassaiss, have a lower length/width ratio (1·30) than the narrower specimens from Said (1·42).

The most marked macroscopic feature of the shell in this species is the broadly reflexed, straight collumella and wide umbilicus. On dead shells collected at Said there is a very strongly marked reticulate sculpture which can be seen clearly with a hand lens but fresh, translucent shells require more careful examination.

Preliminary observations on the anatomy of this material showed that it differed in several respects from the descriptions published by Mandahl-Barth (1954 & 1957). Three specimens from Kisumu, Kenya, were therefore dissected for comparison. The mantle in the snails from Aden appears uniformly black, due to the dense and

even distribution of chromatophores, and it has a pale grey margin which is often reflexed over the edge of the aperture ; the mantle markings of the Kisumu specimens are regular black spots and blotches on a light grey ground. The male copulatory organ is very large relative to the size of the animals, about 3·5–4·0 mm. total length in a 5 mm. shell (Text-figs. 2 and 3). According to Mandahl-Barth the preputium is exceptionally big and it is wider and longer than the sheath. In material from both localities in Aden the sheath is a little longer than the preputium and its maximum diameter is at least equal to that of the distal part. The specimens from Kisumu have the sheath and preputium roughly equal in length and in only one of the three dissected was the preputium conspicuously wider than the sheath. The epiphallus is short. Mandahl-Barth refers to the radula teeth of *B. reticulatus* as very small and with the endo- and mesocones not completely separated. The teeth of the Kenyan specimens are certainly small and the cusps are fine and lanceolate but there is scarcely any fusion of the inner and middle cusps of the laterals (Text-fig. 9). The Aden specimens, on the other hand, have larger teeth, the mesocones of the laterals are very big and spatulate and the endocones are reduced to small points on the inner margins of the mesocones (Text-fig. 8). There are eight or nine laterals in the Aden radulae and twelve to fourteen marginals while those from Kisumu have six or seven laterals and sixteen to eighteen marginals. The marginals of the Kenyan specimens are more delicately pectinate than those from Aden.

B. reticulatus in East Africa is known only from temporary habitats and it seems likely that the pools at Said and Rassaiss may not be permanent. Water originating from some springs in the Wadi Hatib has a high mineral content which results in a white crust being deposited around the edge of drying pools. Well-water from Nisab has a total dissolved solids content of about 1750 p.p.m. of which 480 p.p.m. are total hardness and about 550 p.p.m. are sodium chloride. Analysis of a small sample of water from the pool at Rassaiss (carried out by the laboratory of the Government Chemist, London) showed total dissolved solids of only 200 p.p.m. of which 40 p.p.m. were total hardness and 60 p.p.m. sodium salts. This suggests that the pool is filled largely by rainwater rather than from a spring and it is almost certain, therefore, to dry out periodically. The only other animals found in the Rassaiss pool were a single pair of waterbeetles, *Hydaticus jucundus* (Reiche) and a number of anostracan crustacea, kindly identified for me by Dr. J. Harding as *Streptocephalus neumanni* Thiele ; both of these species are characteristic elements of ephemeral waters.

Connolly (1947) described in some detail a large sample of what he considered to be a variety of *B. truncatus* from Al Bahr in the Hadhramaut and he mentioned that they were so different from the typical form that they might be considered to be a separate species. These specimens have been re-examined and proved to be *B. reticulatus*. The isolated and obscure habitats in which the snails occur at Rassaiss and Said, also their probably temporary nature, suggest that this species is likely to be overlooked in any routine survey for medically important snails. It was because the Marbum pools at Said were reputed to be the local source of infection with urinary schistosomiasis that they were visited and the pool at Rassaiss was found only by chance. From three records for the species in Southern Arabia it is impossible to guess at its distribution but it is likely to be found in the middle heights throughout

the Protectorate and possibly in Yemen also. Epidemiological evidence points to this snail as the intermediate host of *Schistosoma haematobium* at Said and specimens from Rassaiss have proved to be excellent hosts in the laboratory for the Said strain of parasite. The snails breed easily in the laboratory, the egg-masses are relatively large for a small bulinid with up to fourteen eggs in each and the size at hatching is smaller than in *B. forskali* but the " infant mortality " rate is lower.

Bulinus beccari (Paladilhe)

(Pl. II, 9–14)

Physa beccarii Paladilhe, 1872, p. 23, Pl. I, figs. 7 & 8.
Bulinus forskalii Azim & Gismann, 1956, p. 436, figs. 18, 19.

Fahdli : Wadi Hasan at Dirgag, Abyan, in shallow, running water with dense aquatic vegetation and a sandy bottom.

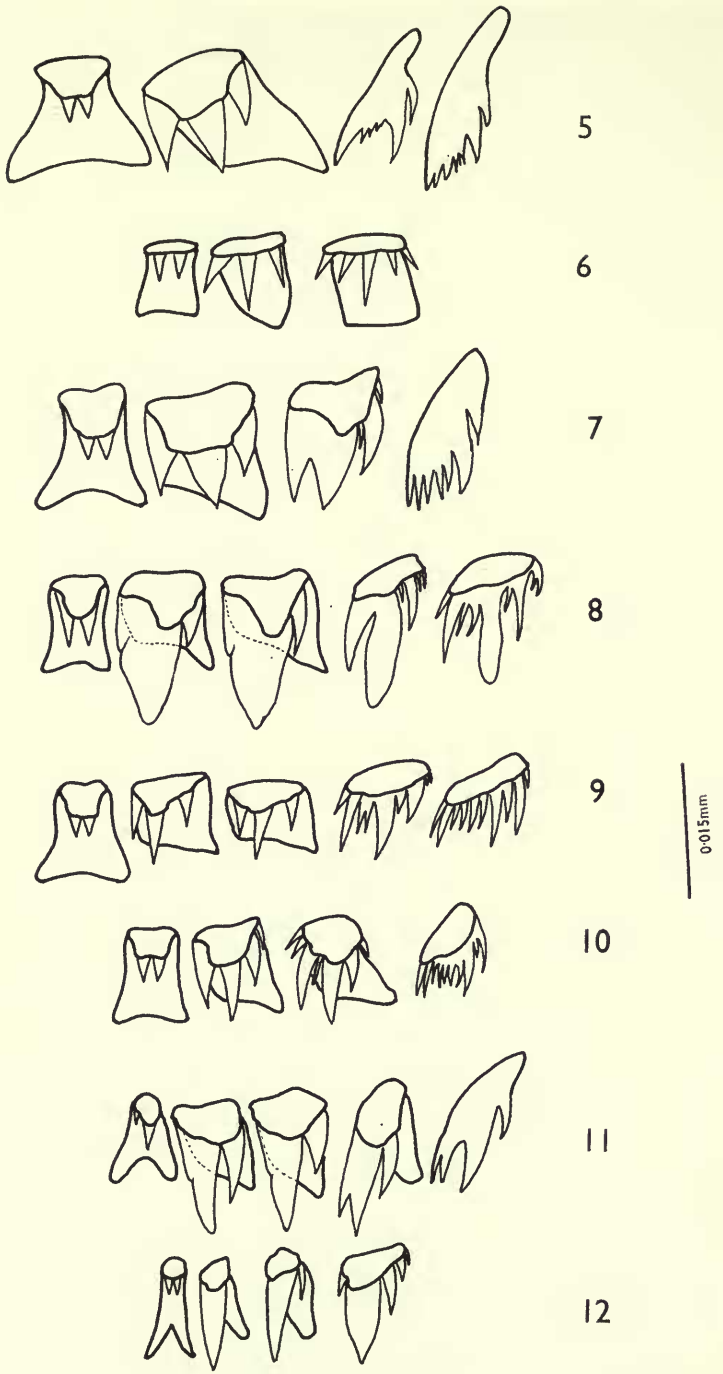
Lower Yafai : Bateis, Abyan, in the Nabwa spring in cool, relatively deep gently flowing water on *Ceratophyllum* and other aquatic plants, also a single living specimen and one dead shell in the Wadi Bana under a stone in shallow, fast-running water.

The shell is high-spired and elongate, translucent white, without marked ribbing and with a slight carination forming an ill-defined shoulder on the earlier whorls. The columella is slightly twisted at its upper end and its margin is reflexed, almost closing the umbilicus. The largest specimens seen (from Dirgag) have a shell-length of 7·3 mm. but the majority of adult specimens in both of the large samples do not exceed 6·0 mm. shell-length, with maximum width 3·4 mm. and aperture length also 3·4 mm.

The anatomy of the animal is in no way exceptional. The mantle is light grey, densely spotted with black and the rest of the body is darkly pigmented so that the living snail appears black. The male copulatory organ is like that of most members of the *B. forskali* group, the sheath is a little longer and narrower than the preputium and the epiphallus is short. The radula teeth are smaller than in *B. forskali*, the cusps of the laterals are long and lanceolate and, in the majority of specimens there is an accessory cusp high up on the outer edge of the ectocones (Text-fig. 10).

The affinities of *B. beccari* have never been clear. Paladilhe recognized that it was closely related to many species characteristic of the African fauna but he was able to distinguish between it and *lamellosa* Roth and *vitrea* " Parreys ", both now regarded as synonyms for *B. forskali* (Ehrenberg). Germain (1921) included *beccari* with the Mauritian species *cernicus* in the synonomy of *forskali* and Mandahl-Barth (1957), following Germain, provisionally placed *beccari* in the synonomy of *cernicus*. The general appearance of the shell of *beccari* is close to some forms of *senegalensis* from the Gambia (Wright, 1959*b*) but it is distinguished from that species by the presence (on most specimens) of a weak carination on the upper part of the early whorls. *B. beccari* differs from most forms of *B. forskali* in the poorly developed ribbing of even the early whorls and in its generally more obese body whorl and less exserted spire. The radula teeth are smaller than *senegalensis*, *forskali* or *scalaris* and there is no fusion of the endo- and mesocones of the laterals as in *cernicus*.

The importance of *B. beccari* as an intermediate host for *Schistosoma haematobium*



Radula teeth.

FIG. 5. *Biomphalaria rueppelli*. Central, 1, 11 and 16.

FIG. 6. *Gyraulus convexiusculus*. Central, 1 and 15.

FIG. 7. *Bulinus sericinus*. Central, 1, 6 and 12.

FIG. 8. *B. reticulatus* from Rassaiss. Central, 1, 2, 9 and 16.

in the coastal plain regions of Aden is described elsewhere (Wright, in press). The ability of the species to act as a host for this parasite suggests possible affinities with either *B. senegalensis* or *B. cernicus*. Ecologically *beccari* differs from *senegalensis*, a snail so far only known from temporary rain pools with a low calcium content, in that it is found in permanent, flowing water with a high calcium content.

Family *LYMNAEIDAE*

Lymnaea truncaluta (Müller)

(Pl. I, 18–20)

Buccinum truncatulum Müller 1774, vol. II, p. 130.
Lymnaea (*Galba*) *truncatula* Connolly, 1941, p. 33.

Upper Aulaqi: Tarbak, Wadi Amhadu (part of Wadi Hatib), under small stones and amongst gravel both in the water and on the edge of the stream at a point where it was flowing rapidly.

Several dozen specimens of this species were collected from a very localized and unusual habitat. The shells do not differ in any significant respect from specimens from the Ethiopian highlands (Wright & Brown, 1962) and the anatomy of the reproductive system shows no unusual characters. The radula teeth are interesting in that the first five laterals are all bicuspid, the endocone is reduced to a slight swelling on the inner edge of the mesocone and this cusp and the ectocone are unusually long and dagger-like (Text-fig. 11). The endocone appears as a discrete cusp near the tip of the mesocone in the sixth row and in the next few rows the division becomes more marked. Transition to the marginals occurs by subdivision of the endocone, the ectocone remains undivided and eventually disappears as do most of the divisions of the endocone so that the extreme marginals are bicuspid.

Connolly (1941) recorded two specimens of this species collected from a muddy brook near San'a, Yemen. The present record merely extends its known distribution a little to the south and east.

Family *ANCYLIDAE*

(Pl. II, 15–22)

Ancylus fluviatilis Müller. 1774, Vol. II, p. 201

Pseudancylus abyssinicus Connolly, 1941, p. 34.
Pseudancylus argenteus Connolly, 1941, p. 37, Pl. III, figs. 11–12.

Upper Aulaqi: Sumayfah, Wadi Yeshbum, from a deep, shaded rock-pool in a side gulley near Yeshbum, about 3,200 ft.

Tarbak, Wadi Amhadu (part of Wadi Hatib), from the rocky sides of a swift-flowing, shallow channel, in the stream bed, about 4,500 ft.

There are no obvious differences between the ancylids collected in Upper Aulaqi and European specimens of *A. fluviatilis*. The description of the genital system of this species by Lacaze-Duthiers (1899) differs only from the Aden material in that

he shows the flagellum to open into the penis sheath while in my specimens the duct appears to open separately into the preputium (Text-fig. 4); this is a character which could so easily be affected by fixation methods that it cannot be regarded as having any taxonomic importance.

Connolly (1941) described *Pseudancylus argenteus* from pools in Shab Samua, Hureidha in the Hadhramaut and recorded *P. abyssinicus* (Jickeli) from a pond near Haz in Yemen. In the collection of the British Museum (Natural History) there is a sample of *P. argenteus* (identified by Connolly) from Mesayid, Yemen. The shells of my material from Sumayfah compare well with Connolly's *abyssinicus* and the larger specimens from Tarbak are only distinguishable from Connolly's Yemen material of *argenteus* by their darker colour. The type series of *argenteus* have the apex of the shell less sharply recurved than in the other samples. Connolly noted that in *argenteus* the ectocone of the marginal radula teeth is unicuspid while in *abyssinicus* and *fluviatilis* the ectocone is subdivided. This observation was based on radula preparations made from the type series of *argenteus* and from the Yemen sample of *abyssinicus*. Re-examination of the original slides shows that this character is slightly variable. In the majority of my specimens the ectocone is unicuspid but in one radula it is undivided in the marginals on one side and bicuspid on the other (Text-fig. 12).

Attention was drawn to the similarity between the radulae of *Ancylus fluviatilis* and *abyssinicus* by Jickeli (1874) and the close relationship between the two species was emphasized by Walker (1914). When preserved material from the highlands of Ethiopia becomes available it is almost certain that the anatomical identity of *abyssinicus* with *fluviatilis* will be confirmed. The range of this Palearctic species must now be extended to include the highland areas of South-west Arabia.

Family *THIARIDAE*

Melanoides tuberculata (Müller)

(Pl. II, 23)

Nerita tuberculata Müller, 1774, Vol. II, p. 191.
Melanoides tuberculata Connolly, 1941, p. 35.

Fahdli: Wadi Hasan at Dirgag, Abyan.
Lower Yafai: Nabwa spring and Wadi Bana, Bateis, Abyan.
Upper Aulaqi: As Sufal, Wadi Yeshbum and several places in the Wadi Hatib.
Haushabi: Wadi Tiban at Museimir.

This species is almost universal in its distribution in South-west Arabia, usually in gently flowing water. Specimens from Abyan in the coastal plain reach a greater maximum size than those from the hill regions.

DISCUSSION

All of the species in this collection have been obtained before in various parts of South-west Arabia but this is the first material which has been subjected to detailed anatomical examination to elucidate the relationships of some of the species. Thus,

Biomphalaria arabica is shown to be indistinguishable from *B. rueppelli* of Ethiopian origin, the *Bulinus truncatus* of most previous authors is more closely related to the highland species, *B. sericinus*, Connolly's *B. truncatus* var. from the Hadhramaut is the rare East African *B. reticulatus* and *Pseudancylus argenteus* and *P. abyssinicus* are only local forms of *Ancylus fluviatilis*. The specimens collected in Upper Aulaqi state are the first from that area and all thus provide new locality records which either extend or fill in gaps in known distribution patterns.

Connolly (1941) noted a marked difference between the non-marine molluscan fauna of South-west Arabia and that of Hejaz and Nejd. Mattingly and Knight (1956) found that the boundary line between the Palearctic and Ethiopian zoogeographical regions defined by Chapin (1923) on the basis of the avifauna also holds good for the mosquitoes of Arabia. This line runs roughly south-east from a point on the Red Sea coast near Jedda to the coast of Oman opposite the Kuria Muria Islands, and, as a result, places the whole of Yemen and the Aden Protectorates in the Ethiopian region. Scott (1939) in a general account of the natural history of South-west Arabia pointed out that the major regional component of the flora and fauna of the hot valleys is African modified by an Oriental influence while in the highlands there is a well-marked Palearctic element. An analysis of the regional components of the mosquito fauna of Arabia as a whole by Mattingly and Knight showed that the bulk of the species are Palearctic but that there is a strong Ethiopian element in the South-west and the Oriental influence is small and mostly confined to the coast. These authors also concluded that the mosquito fauna of Socotra is predominantly Palearctic.

The freshwater molluscs appear to conform well to the general zoogeographical picture in South-west Arabia. Many of the older records are not sufficiently reliable for consideration but, through the kindness of Dr. Ruth Turner of the Museum of Comparative Zoology at Harvard I have been able to examine material collected by Dr. R. E. Kuntz in Yemen and identified by Dr. J. Bequaert. These specimens, in conjunction with my own and material in the collection of the British Museum (Natural History) provide a reasonable basis for discussion.

The principal influence is clearly Ethiopian and, in the highland areas, this influence can be seen in the narrow political–geographical sense rather than the broader zoogeographical meaning of the adjective. Both *Biomphalaria rueppelli* and *Bulinus sericinus* are characteristic of the highlands of Abyssinia and the relationship is further reinforced by Kuntz's specimens of *Segmentorbis angusta* (Jickeli) found near Ma'bar, Yemen. Mattingly and Knight (loc. cit.) pointed out that the number of Ethiopian species in the Arabian mosquito fauna is inclined to be exaggerated by the inclusion of forms whose distribution in the Ethiopian region is limited and which are more accurately assigned to the Palearctic. This is also the case with the freshwater mollusca in that *Lymnaea truncatula*, *Ancylus fluviatilis* and *Pisidium casertanum* are common to both the Abyssinian and South-west Arabian highlands but are, in fact widely distributed Palearctic species. Regardless of their wider distribution, the presence of these three species isolated in the highland areas on both sides of the southern Red Sea provides very strong evidence in favour of a common origin of the two faunas.

Both *Bulinus beccari* and *B. reticulatus* are obvious African elements. *B. beccari* appears to be an endemic Arabian form but more detailed investigations of the coastal regions of North-east Africa may reveal its presence there. It is very close to some forms of *B. forskali* and it has been confused with that species in the past. It is probably merely a local race of *B. forskali*, no more entitled to specific distinction than many other races, but for its obvious epidemiological importance. *B. reticulatus* presents exactly the opposite problems to those posed by *B. beccari*. It is not a well-known species and the full range of its variation has not been studied ; the material from Aden differs markedly in characters of the radula and male copulatory organ from topotype specimens from Kenya and the Aden form is also a proven host for *Schistosoma haematobium* but the intermediate host potential of African *B. reticulatus* has not been investigated. In another paper (Wright, in press) I have suggested that *B. crystallinus* and *B. camerunensis* may be relicts of an ancestral bulinid stock and it is possible that *B. reticulatus* also falls into this category. If this is the case then considerable differences are to be expected between isolated populations of an ancient form and morphological differences such as those found between Arabian and Kenyan *B. reticulatus* suggest a long period of separation.

A further possible Ethiopian influence in the Arabian fauna is *Lymnaea arabica* Smith, 1894. Hubendick (1951) considers that the species is probably a local form of the extremely variable African *L. natalensis*. Specimens collected by Kuntz in Yemen were identified by Bequaert as *L. exserta*, a form of *L. natalensis* and several samples in the collection of the British Museum (Natural History) from Yemen, Western Aden Protectorate and Dhurfar have been assigned to *L. caillaudi*, also a synonym of *L. natalensis*. However, Connolly (1941) recorded *L. auricularia* from near San'a, Yemen and Dr. Bequaert also identified samples collected by Kuntz from near M'bar and Dhamar as this species. Hubendick (1951) treats *L. natalensis* as the African part of the *L. auricularia* super-species which extends throughout the Palearctic and Oriental regions. However, *L. auricularia*, *L. natalensis* and some of the Oriental forms of *L. auricularia* can be distinguished from one another by the chromatographic pattern of fluorescent substances in their body-surface mucus (Wright, 1959*a*). Unfortunately no material belonging to this complex was found during the present survey but, if living specimens become available for study in the future, it should be possible to decide whether they are derived from Ethiopian, Palearctic or Oriental origins.

The only clearly Oriental element in the present collection is *Gyraulus convexiusculus*, a species described originally from Afghanistan but with a wide range in South-east Asia. Kuntz collected a large sample of this species near San'a, Yemen and Connolly records it from Wadi Jedd in the Hadrhamaut. Pallary (1928) reported *Indoplanorbis exustus* from Muscat and Connolly included this species in his faunal list for Southern Arabia but expressed doubts as to the correct identification of the material. However, Pallary's specimens are in the collection of the British Museum (Natural History) and I am able to confirm that they are shells of *I. exustus*. Two samples in Kuntz's Yemen collection identified as this species are in fact *Biomphalaria rueppelli* and Pallary's specimens are the only confirmed record for *I. exustus* in Southern Arabia. Muscat lies in the extreme south-eastern corner of the Arabian

peninsula on the Persian Gulf, the commonly accepted boundary between the Palearctic and the Oriental regions, and the presence of this typically Oriental species is not, therefore, surprising. A collection of freshwater gastropods from Socotra has been examined and in five large samples the dominant species present was *I. exustus*, an Oriental influence which is in contrast to Mattingly and Knight's comments on the predominantly Palearctic nature of the island's mosquito fauna. The only other species present in the Socotran collection was *Melanoides tuberculata* an almost ubiquitous prosobranch with a range extending from West Africa through to South-east Asia. In the Western Aden Protectorate this is the most abundant species of snail and, with the possible exception of *Gyraulus convexiusculus*, is the only one that occurs both in the coastal plain and in the highlands.

The conclusions reached by this examination of the relationships of the freshwater gastropods of South-west Arabia are in accordance with the general zoogeographical trends in the area. The principle influence is Ethiopian with a Palearctic component in the highlands (a component which is shared with the Ethiopian highlands) and a small Oriental element which appears to have a wide altitudinal range. Recent surveys by medical parasitologists have given the impression that the molluscan fauna of the area is of the Mediterranean type. This impression was created by the treatment of *Biomphalaria arabica* as a sub-species of the *alexandrina* group rather than as a member of the *pfeifferi* complex, by the failure to recognize the differences between the highland *Bulinus sericinus* and the lowland *B. truncatus* and by the automatic inclusion of *B. beccari* in the synonomy of *B. forskali*. That these apparently academic points have an epidemiological significance is shown by the failure of attempts to infect Middle Eastern strains of *B. truncatus* with two strains of *Schistosoma haematobium* from the Western Aden Protectorate (Wright, in press). They explain also Witenberg and Saliternik's (1957) failure to infect Israeli *B. truncatus* with *S. haematobium* obtained from Yemeni immigrants.

SUMMARY

Anatomical study of a small collection of freshwater gastropods from the Western Aden Protectorate has permitted a reassessment of the affinities of some of the species recorded from South-west Arabia. The species represented in the collection are *Biomphalaria rueppelli*, *Gyraulus convexiusculus*, *Bulinus sericinus*, *B. reticulatus*, *B. beccari*, *Lymnaea truncatula*, *Ancylus fluviatilis* and *Melanoides tuberculata*. The zoogeographical aspects of the basommatophoran fauna are discussed and the epidemiological significance of the bulinids as intermediate hosts for human blood-flukes is mentioned.

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